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UNITED STATES
DEPARTMENT OF THE INTERIOR
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BUREAU OF MINES
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TRANSPORTATION OF IRON ORE, UNDERGROUND MINES LAKE SUPERIOR DISTRICT

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JOHN A. JOHNSON AND FRANK E. CASH

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TRANSPORTATION OF IRON ORE, UNDERGROUND MINES, LAKE SUPERIOR DISTRICT[1]

By John A. Johnson[2] and Frank E. Cash[3]

CONTENTS

	Page
Introduction	2
Scope	2
Acknowledgments	3
Moving ore from the working place	3
Scraping	5
Scrapers	5
Scraper hoists	6
Shaker conveyors and belt conveyors	6
Loading cars from chutes	7
Loading cars from loading drifts	8
Underground haulage	8
Underground cars	8
Trains	10
Locomotives	10
Track	11
Shaft stations and hoisting shafts	12
Dumping cars	12
Storage pockets	14
Auxiliary storage trenches	14
Hoisting shafts	15
Skips, cages, and hoists	15
Skips	15
Cages	16
Hoists	16
Head frames and stock pile haulage	18
Head frames	18
Stock-pile haulage	20
Accident statistics	20

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ILLUSTRATIONS

Fig.		Following page
1.	Arrowhead scraper designed and built in local mine shops	4
2.	Transfer drift under sublevel stope, using 60-inch scraper; floodlight at upper left	4
3.	Rotary-dump-type, 3-1/2-ton car with cowbell attached to rear	4
4.	Four-ton rocker-dump-type car with storage-battery tail light on rear	10
5.	Steel flush plate over haulage-track switch throw	10
6.	Hand-operated block-signal light	10
7.	Switch-stand signal lights operated from bridle bar	10
8.	Twin two-car rotary dumps	12
9.	Ore-storage trench at shaft station	14
10.	Headframe loading pocket and steel monoleg stocking trestle	18
11.	Ten-ton remote-control-operated larry car	18

INTRODUCTION

The operators of the Lake Superior district iron-ore mines have made tremendous progress in the past 25 years in the transportation of broken ore from the working places to the surface. This progress has paid dividends in increased production and in lower accident-frequency rates. The trend has been toward more efficient use of mechanical and electrical power and abolishment of many of the backbreaking tasks formerly required of miners and trammers.

Scope

Transportation of iron ore as described in this paper covers (1) movement from the working place to ore raises by scrapers, shaker conveyors, and belt conveyors and loading underground cars from chutes or by scraping from loading drifts; (2) underground haulage, which includes underground cars, trains, locomotives, and track; (3) shaft stations and hoisting shafts, which includes dumping cars, storage pockets, auxiliary storage trenches, and shafts; (4) hoisting, which consists of skips, cages, and hoists; and (5) head frames, loading into railroad cars, and stock-pile haulage.

The 19 underground iron-ore mines discussed in this paper, situated in the Menominee, Marquette, Gogebic, Cuyuna, Mesabi, and Vermilion iron ranges of Michigan, Wisconsin, and Minnesota, shipped about 9,000,000 tons of iron ore in 1945, which constituted 56 percent of the underground iron ore taken from the Lake Superior district.

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The purpose of this circular is to discuss briefly the types of equipment used and to disseminate information as to some of the modern practices in the transportation of iron ore in use at the underground mines of the district.

Acknowledgments

The authors gratefully acknowledge the information and assistance given and the numerous courtesies extended to them by the following mining companies and their officials: The Cleveland-Cliffs Iron Co., The M. A. Hanna Co., Inland Steel Co., North Range Mining Co., Oglebay, Norton & Co., Oliver Iron Mining Co., Pickands, Mather & Co., Republic Steel Corp.

MOVING ORE FROM THE WORKING PLACE

The old-time laborious method of hand-loading broken ore into wheelbarrows, "buggies", and tram cars at the working place and hand-tramming the ore away from the place was discontinued in the Lake Superior district iron-ore mines many years ago. At present, nearly all ore is moved from the working face by scrapers; frequently, however, either compressed air-operated or electrically operated mechanical loaders are employed to load broken ore or rock in development headings. In one mine, where the ore is mined by sublevel stoping, shaker conveyors have been installed to move the broken ore from the bottom of stope mills to ore raises. In another mine, where the ore is mined by slicing, the ore is scraped from the working faces to a mining crosscut, from which place the ore is transported by shaker conveyors to a main-haulage conveyor belt. (See table 1 for a summary of data on moving ore from the working face.)

Experiments with underground mechanical loading devices began about 1900. Serious attention was not given to this problem until World War I had created a shortage of labor; shovel loaders and scraper loaders were introduced at that time. The small underground power shovel first seemed to be the best means for reducing mucking costs, and during World War I many kinds of shovel loaders were developed. Rapid progress was made, meanwhile, in the development and use of scraper loaders, and many operators found them more practicable than any other available method. By 1924, shovel loaders were passing out of favor, and scrapers became the predominant mucking mechanism at most iron mines.4/

4/ Eaton, Lucien, Technology, Employment, and Output Per Man in Iron Mining: Works Progress Administration National Research Project and Bureau of Mines Report E-13, June 1940, pp. 141-159.

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TABLE 1. - Moving ore from the working place

Mine, and mining method	Scrapers					Scraper hoists		Chute gates, type
	Type	Width, inches	Lip material	Rope diameter, inches	Maximum distance scraped, feet	Horsepower	Voltage	
A Radial top slicing	Hoe	42	Manganese steel	3/8 - 1/2	85	15 and 25	440 a.c.	Hand-operated arc.
B Slicing	Box	48, 54 and 60	Crucible steel	1/2 - 5/8	55	15, 25, and 30	440 a.c.	None.
C Stoping and sublevel caving	Hoe	36 and 48	Manganese steel	3/8 - 1/2, 5/8 - 3/4	100	15, 25, and 35	440 a.c.	Board stoppers.
D Top slicing and sublevel caving	Box	42, 48 and 60	Manganese steel	3/8 - 1/2	200	15, 20, and 25	250 d.c.	Hand-operated arc.
E Sublevel stoping	Hoe	30, 42 and 48	Manganese steel	3/8 - 1/2 1/2 - 5/8	250	7-1/2, 15, 25, and 35	440 a.c. and 250 d.c.	Board stoppers.
F Sublevel caving	Semi-hoe	42, 48 and 52	Molychrome nickel steel	3/8 - 1/2 5/8 - 3/4	200	15, 25, and 40	275 d.c.	None, load directly into cars.
G Sublevel caving	Box and hoe	42, 48 and 52	Manganese steel	3/8 - 7/16 1/2 - 5/8	150	15, 20, 25 and 40	440 a.c.	Load directly into cars.
H Top slicing	Box and hoe	48 and 60	Carbon steel	3/8 - 1/2	130	20 and 40	440 a.c.	None, load directly into cars.
I Sublevel stoping	Semi-hoe	30, 42, and 48	Manganese steel and studite	1/4 - 3/8, 3/8 - 1/2, 1/2 - 5/8	150	7, 15, 25, 40, and 50	440 a.c.	Board stoppers.
J Radial top slicing	Box	42 and 48	Manganese steel	7/16 - 1/2	130	15, 20, and 25	250 d.c.	Hand-operated arc.
K Top slicing and sublevel caving	Hoe	42 and 60	Manganese steel	1/2 - 1/2	380	15 and 25	250 d.c.	Hand-operated arc.
L Sublevel caving and sublevel stoping	Hoe	48 and 60	Manganese steel	1/2 - 5/8 5/8 - 3/4	150	20 and 40	440 a.c.	Hand-operated arc.
M Sublevel caving	Semi-hoe	52	Cast molychrome steel	1/2 - 5/8	185	25	250 d.c.	None, load directly into cars.
N Top slicing and sublevel stoping	Hoe	42 and 48	Manganese steel	1/2 - 1/2	200	20	440 a.c.	Hand-operated arc.
O Top slicing and sublevel stoping	Box	42 and 48	Manganese steel	7/16 - 1/2	120	15, 20 and 25	250 d.c.	Hand-operated arc.
P Sublevel caving	Hoe	60	Carbon steel	3/8 - 1/2	225	25	250 d.c.	Board stoppers.
Q Sublevel caving	Hoe	60	Manganese steel	1/2 - 5/8	150	25	250 d.c.	None.
R Sublevel caving	Box	42, 48, and 54	Cast molychrome steel	1/2 - 5/8 5/8 - 3/4	150	20, 25, and 30	440 a.c.	Some hand-operated arc. Mostly scrape directly into cars.
S Sublevel caving	Semi-hoe	44, 48, and 54	Molychrome nickel steel	1/2 - 5/8 5/8 - 3/4	150	15, 20, 25, and 40	440 a.c.	Board stoppers.

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Figure 1. - Arrowhead scraper designed and built in local mine shops.

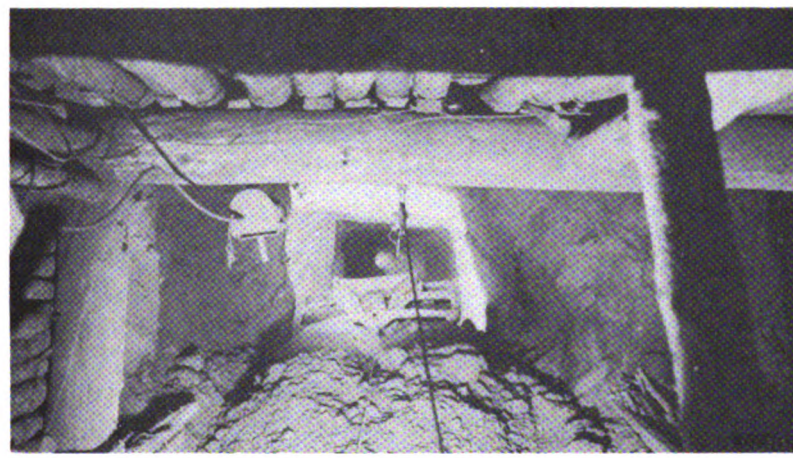

Figure 2. - Transfer drift under sublevel stope, using 60-inch scraper; floodlight at upper left.

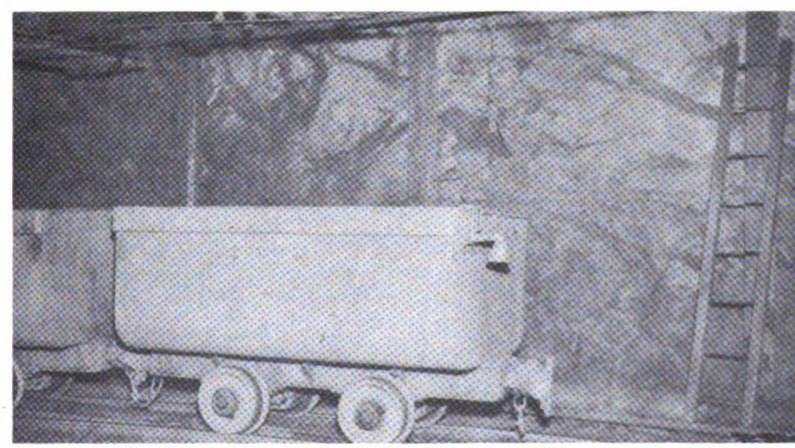

Figure 3. - Rotary dump-type, $3\frac{1}{2}$-ton car with cowbell attached to rear.

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Scraping

In the first application of scraper mucking or slushing in underground mines (about 1898), the slip scraper, largely of the type in use on farms or in road work, was pulled from the face by a single-drum compressed air-operated hoist and pulled back to the face by manpower.5/ The greatest growth in the use of power scrapers in iron-ore mining took place from 1920 to 1929, many mines changing from hand shoveling to power scraping in the 3-year period 1920 to 1923. Until about 1924, all scraper hoists used underground in the Lake Superior Region were compressed air-operated. With a demand for increased rope speeds and larger scrapers, electric scraper hoists were developed.6/

The modern scraper installation is a transportation unit as well as a loading unit. The scraper is used (1) to load the ore from development headings into underground tram cars; (2) to move ore from working places to ore raises in slicing, sublevel caving, sublevel stoping, and open-stoping mining methods; (3) for loading ore directly into tram cars from slushing or scraper-loading drifts, which have replaced chutes for tram-car loading in many iron-ore mines; and (4) to move ore from the auxiliary storage trenches to the skips at shaft stations.

Scrapers

Scrapers used in the Lake Superior district iron-ore mines are either of steel-plate construction made in the mine shops or of cast-steel construction purchased from mining equipment-manufacturing companies. The design and size of the scraper depends on the type of ore to be moved. Scrapers are usually made in (1) the hoe type, (2) semi-hoe or partial-box type, (3) the box type, and (4) modifications of these types. The hoe-type scraper is generally used for chunky material and tends to lose part of its load when moving fine material. The box-type scraper is best suited for moving fine material.

Some companies use an arrowhead-type scraper that is a modification of either the hoe-type or semi-hoe-type scraper. The arrowhead-type scraper has two cutting edges, either one of which can be used by turning the scraper upside-down. Both cutting edges may be the blade type, or one cutting edge may have teeth for handling chunky material. (See fig. 1.)

Scrapers used range in width from 30 to 60 inches, the 60-inch scraper being used on special jobs, such as in transfer drifts (see fig. 2) or in auxiliary storage trenches at shaft stations. The 42- and 48-inch scrapers are used most commonly.

Most mines use scraper blades or lips of manganese steel; however, high-carbon steel, molychrome steel, and molychrome-nickel steel also are used.

5/ Ingersoll-Rand Co., New York City, Modern Methods for Scraper Mucking and Loading: Form No. 2412, 1939, p. 3.

6/ Work cited in footnote 4.

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Wire ropes used to pull the scrapers range in diameter from 3/8 to 3/4 inch, and the diameter of the return ropes ranges from 1/4 to 5/8 inch. The most common sizes used are 5/8-inch pull cable and 1/2-inch return cable. The maximum distance ore is scraped ranges from 55 to 380 feet, 170 feet being the average.

Scraper Hoists

Generally, double-drum scraper hoists driven by 15-, 20-, or 25-horsepower, 440-volt, alternating-current motors are used. A few 30-, 35-, 40-, or 50-horsepower hoists are used on transfer subs with the larger scrapers, and a few hoists are driven by 250- or 275-volt direct-current motors. At one mine a 30-horsepower, electric, scraper hoist is operated by push-button remote control and has a limit-control mechanism similar to that on a Lilly hoist control, which automatically controls the distance traveled by the scraper.

Shaker Conveyors and Belt Conveyors

In one mine7/ producing about 300,000 tons of iron ore annually by sublevel stoping, it was found that scraping the broken ore for 150 or 200 feet was not efficient because of the time lost in pulling back the empty scraper. A shaker-conveyor unit was installed in one of the scraper subdrifts as an experiment. The broken ore from the stope runs through mills to the grizzly sublevel, where the large chunks are broken; from the grizzly sublevel the ore runs through raises to self-feeding chutes, and then to the shaker conveyor, which carries the ore to the ore raise and loading chute.

As the movement of ore on a shaker conveyor is almost continuous, the distance from the stope to the ore raise and loading chute does not limit the amount of ore that can be handled by a shaker conveyor up to the limit of its capacity, as it does in scraper operations. One shaker-conveyor unit can be used on distances up to 250 or 300 feet. Additional units can be installed in series for longer distances. To increase the life of the shaker-conveyor unit, 3/16-inch liner plates are spot-welded onto the pans before the unit is installed.

The cost per ton of handling ore at this mine with a shaker conveyor has been about 37 percent less than handling with scrapers. At least three shaker-conveyor units have been used successfully. The management plans to replace scrapers with shaker conveyors in all stoping places, and also plans to shake the ore directly onto a belt-conveyor system for transportation to the shaft pocket, replacing rail haulage, on the next operating level, thereby decreasing the accident hazard due to rail haulage.

7/ Satterley, R. D., Shaker Conveyors Used in Sublevel Stoping in an Iron-Ore Mine: Am. Inst. Min. and Met. Eng., Min. Technol., May 1945, 8 pp.

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At another mine with a flat bed of iron ore, the broken ore is moved from the working places to the shaft station by scrapers, shaker conveyors, and belt conveyors exclusively. Development, all in ore, consists of a main belt-conveyor drift extending from the shaft pocket to the limit of the ore body, feeder belt-conveyor crosscuts driven at 350-foot intervals at right angles to the main belt-conveyor drift, and mining shaker-conveyor drifts driven at 110-foot intervals at right angles to the feeder belt-conveyor crosscuts.

Mining is started at the far end of and at right angles to the mining shaker-conveyor drifts by driving two 10-foot-wide slices directly opposite each other. The broken ore is scraped from the faces of the slices to a hopper in the mining shaker-conveyor drift with a 60-inch box-type scraper pulled by a 440-volt, double-drum, electric hoist.

Shaker conveyors powered by 30-horsepower, 220-volt, alternating-current motors convey the ore from the hopper at the intersection of the mining drift and the slices to a feeder belt-conveyor crosscut. Several 10-foot pan sections are connected to form a shaker-conveyor unit, and the maximum length of one unit is usually restricted to 300 feet, but it can be as long as 350 feet. The unit operates at about 80 strokes per minute, and the length of stroke can be adjusted to vary from 5 to 10 inches. The maximum capacity of a unit is about 120 tons per hour.

Thirty-inch-wide belt conveyors powered by 30- or 40-horsepower, 220-volt, alternating-current motors convey the ore from the shaker conveyors through the feeder belt-conveyor crosscuts and the main belt-conveyor drifts to the shaft station pocket. In the long drifts and crosscuts, two 600-foot belt-conveyor units are installed in tandem. The belts are cut and spliced to form any length desired up to 600 feet. The belt-conveyor units travel 350 to 400 feet per minute and handle the ore of four to six shaker-conveyor units.

Loading Cars from Chutes

In many mines the haulage crews (motormen and brakemen) fill the cars when they are loaded from chutes; in some mines chute trammers or loaders stay at the ore chutes and load cars for the motormen. Generally, two types of chute gates are used - the overcut arc gate and a combination of board stoppers. Platforms for the loaders to stand on while loading cars are installed at most chutes. At one mine, hinged loading platforms constructed of metal strips were installed at chutes on curves; the platform could be raised out of the way when not in use.

Table 7 shows that 53 lost-time injuries, or 25 percent of the lost-time injuries from "hoisting, haulage, and loading ore and rock," occurred while loading tram cars at chutes during 1944 and 1945.

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Loading Cars from Loading Drifts

Although the method of loading cars from chutes is still being used widely, in several mines the iron ore from sublevel mining operations is loaded directly into cars by scraping from loading drifts. The scraper loading drifts are driven at right angles to the haulage crosscuts, the floor of the loading drift being 5 to 10 feet higher than the floor of the haulage crosscut. The interval between loading drifts is often such that two cars in one train can be loaded simultaneously.

Users of scraper loading drifts 8/9/ claim the following advantage over the chute method of loading cars: (1) One loading drift may replace as many as ten loading chutes; (2) barring chunks, which caused many accidents, is greatly reduced, and accidental contacts of bars with the trolley line are prevented; (3) rushes of ore and water from water backing up in a chute are averted in wet ore bodies; (4) ore falling into chutes packs, which requires a great deal of barring and blasting; (5) loading drifts obviate expensive grizzlies and chutes on the tramming level; (6) labor costs when using the scraper loading drifts are about 15 percent less than when using chutes; (7) there is less trouble when handling large chunks of ore than with chutes; (8) loading drifts provide greater extraction of floor pillars; and (9) reduce the moisture content of the ore by better drainage in wet stopes.

UNDERGROUND HAULAGE

Hand tramming and animal haulage are obsolete in the Lake Superior district iron-ore mines, and mechanical haulage is used entirely to transport the broken ore from the working places to the shaft stations. In one mine, belt-conveyors are used in place of track haulage. (See table 2.)

Underground Cars

The trend in the use of mine cars has been toward large-capacity, steel-constructed cars; wooden cars with iron supports are obsolete. Several types and sizes of cars are being used, as follows (in order of the number of cars being used): (1) Rocker-dump, round bottom, 40- to 70-cubic foot, and 2- to 4-ton capacity; (2) side-dump Granby type, 75- to 100-cubic foot, and 4-1/2- to 6-1/2-ton capacity; (3) gable bottom, 47- to 74-cubic foot, and 3- to 4-ton capacity; (4) solid box type, 60-cubic foot, and 3-1/2-ton capacity; and (5) drop-side-dump box type, 65-cubic foot, and 4-ton capacity. The capacity of the cars ranges from 2 tons for a 40-cubic foot car to 6-1/2 tons for a 100-cubic foot car, the average being about 17 cubic feet per ton of broken iron ore.

8/ Fritz, D. E., The Elimination of Chutes for Tram-Car Loading at the Montreal Mine, Lake Superior Mining Section: National Safety Council, June 1942, pp. 32 to 44.

9/ Mahon, R. C., Discussion of paper cited in footnote 8, pp. 44 to 47.

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TABLE 2. - Underground Haulage

Mine and mining methods	Cars							Locomotives				Track				
		Capacity		Diameter of wheels in inches, and type of bearings	Dimensions in inches										Type	
	Type car	Cu. ft.	Tons		Wheel base	Height above rail	Inside width	Inside length	Weight tons	Maximum distance hauled, feet.	Warning signals	Voltage, d.c.	Track gage, inches. Rail weight, pounds.	Curve radius, feet. Grades, percent	Bonding	Switch throw	Signal lights
A Radial top slicing	Gable bottom	55	3-1/4	14 Roller	36	52	48	78	4 6	1,400	Lights and bell.	250	24" 40# and 62#	40' 0.75	Compression bonds indefinite cross-bond interval.	Upright stand.	Overhead at junctions.
B Slicing	Gable bottom	55	3-1/4	16 Roller	30	50	48	82	6	1,000	Lights and siren.	250	24" 30#	50' None	Welded bonds, cross-bonded at switches.	Flat right-angle throw.	Overhead.
C Stoping and sublevel caving	Rocker dump	52	3	14 Roller	36	54	50	86	5 6	2,300	Lights, bell and siren.	250	24" 40#	50' 0.50	Compression bonds, cross-bonded at switches.	Upright stand.	Overhead at junction.
D Top slicing and sublevel caving	Rocker dump	65	4	16 Roller	48	58	48	96	5 6	2,200	Lights and bell.	250	24" 40#	Indefinite 0.50	Welded bonds, cross-bonded each 90 feet and at switches.	Upright stand and flat right-angle throw.	Overhead at ventilation doors.
E Sublevel stoping	Granby	75	5	16 Roller	39	54	47	90	4 6	1,500	Lights and bell.	250	24" 60#	40-75' 0.50	No bonding.	Upright stand.	Overhead at intersections.
F Sublevel caving	Rocker dump	55	3	14 Roller	36	53	48	87	6	4,000	Lights and bell.	275	24" 60#	40-100' 0.75-1.50	Welded bonds, cross-bonded at 200-foot intervals	Parallel flat throw. Some spring switches.	Manually operated overhead block system.
G Sublevel caving	Granby Rocker dump	83 90 45	4-1/2 5 2-1/2	16 Roller 16 Roller	42	57	54	84	6	4,300	Lights and bell.	250	24" 60#	35' 0.25	Welded bonds, cross-bonded every 100 feet to return cable.	Upright spring switches on main line.	Manually operated overhead block system.
H Top slicing	Gable bottom	74	4	16 Roller	36	56	48	84	Use two 4-ton locomotives in tandem	4,000	Lights and bell.	275	24" 60#	35' 3.0	Welded bonds, indefinite cross-bond interval.	Parallel flat throws, have some air-operated spring switches.	Hand-operated overhead lights.
I Sublevel stoping	Drop-side-dump box	65	4	16 Roller	36	45	60	78	5	2,000	Lights and bell, or lights and siren	250	36" 45#	50' 0.50	No bonding.	Flat right-angle throw.	Overhead.
J Radial top slicing	Rocker dump	65	4	16 Roller	48	58	48	96	6	2,600	Lights and bell.	250	30" 40#	75' 0.50-0.75	Welded bonds, cross-bonded at 200-foot intervals.	Flat right-angle throw.	Overhead, operated by hand and by trolley.
K Top slicing and sublevel caving	Rocker dump	56	3	14 Plain	36	52	49	84	5 6	1,800	Bell	250	24" 45#	50' 0.50	Welded bonds, no cross-bonding.	Flat-right-angle throw.	None.
L Sublevel caving and sublevel stoping	Granby	100 90	6-1/2 6	16 Roller 16 Roller	39 39	55 55	52 52	104 94	6 8	3,600	Lights and bell.	275	30" 60#	75' 0.40	Welded bonds, cross-bonded at 200-foot intervals.	Flat right-angle throw.	Overhead, operated by contact on switch throw.
M Sublevel caving	Rocker dump Granby	40 90	2 5	14 Roller 16 Roller	36 39	49 54	48 54	75 90	6	5,000	Lights, bell and siren.	275	24" 40#	35-100' 0.33	Welded bonds, cross-bonded at 200-foot intervals.	Flat right-angle throw on spring switches.	Lights on stand connected to switches.
N Top slicing and sublevel caving	Rocker dump	70	4	16 Roller	48	58	49	96	4 6	2,700	Lights and bell.	250	30" 40# and 60#	50-75' 0.75	Welded bonds on one rail only. No cross-bonding.	Flat right-angle throw.	Overhead signal lights.
O Top slicing and sublevel stoping	Rocker dump	65	4	16 Roller	48	58	48	96	6 8 10	1,800	Lights and bell.	250	30" 40#	75' 0.50-0.75	Welded bonds, cross-bonded at 200-foot intervals.	Flat right-angle throw.	Overhead operated by hand and by switch.
P Sublevel caving	Box	60	3-1/2	14 Roller	30	46	48	72	6	3,000	Lights and bell, some have horn.	250	24" 40#	30' 0.50-0.75	No bonding. Ground connections to rails every 200-foot.	Flat right-angle end parallel throw. Have cover plate.	Overhead hand-operated signal lights.
Q Sublevel caving	Rocker dump Granby	52 75	3 4-1/2	14 Roller 16 Roller	36 39	54 54	50 46	87 90	6	4,000	Lights and bell.	250	24" 40#	75' 0.50-0.75	Welded bonds. Cross-banded to return cable every 200 feet.	Flat right-angle throw.	Manually operated. Overhead signal lights.
R Sublevel caving	Rocker dump Granby	52 100	3 6-1/2	14 Roller 16 Roller	36 42	54 56	49 51	86 104	5 6 8	4,000	Lights and bell	250	24" and 30" 40# and 60#	50-100' 0.50	Welded bonds. Cross-bonded at 200-foot intervals.	Upright right-angle throws.	None.
S Sublevel caving	Rocker dump	45	2-3/4	All 16"	36	52	50	72	6	3,000	Lights and bell.	250	24" 60#	35-50' 0.50	Welded bonds, indefinite cross-bond interval.	Flat right-angle throw.	Overhead lights at crosscuts.
	Rocker dump	65	4		36	52	50	84									
	Gable bottom	47	3	All Roller	36	52	48	72									
	Gable bottom	55	3-1/2		36	52	48	84									

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The wheel base of the cars ranges from 30 to 48 inches, height above rail 45 to 58 inches, inside width 46 to 60 inches, and the inside length 72 to 104 inches. The size of car wheels ranges from 14 to 16 inches in diameter. All cars were equipped with roller bearings except at one mine, where the cars had plain bearings.

Automatic car couplings were used in 15 of the 19 mines under discussion, link-and-pin couplings were used in 3 mines, and a special male-and-female bar coupling with pins was used at 1 mine. Safety chains between adjacent cars in addition to the automatic couplings are used at 3 of the mines.

Trains

The number of cars in a train varies from 4 to 15, depending on various haulage factors, such as grade of track, condition of track, size of car, condition of rolling stock, size of locomotive, and tailroom at loading places and at shaft stations. In all but two of the mines visited, the train of loaded cars was pulled to the shaft by the locomotive. In one of the mines where the loaded train was pushed, a rotary dump was used at the shaft station; this necessitated pushing the cars, as the locomotive could not pass through the rotary dump; in the other mine where the loaded train was pushed to the shaft, the safer method of pulling the loaded train could have been used. Where the brakeman goes to the shaft with the loaded train, the general practice is to have him ride on the locomotive. At a few of the mines the brakeman rides on the last car when going to the shaft and on the locomotive when pushing the empty cars into the mine; at one of the mines a platform was installed on the rear of the last car for the brakeman to ride on.

In all but two of the mines some sort of warning device, such as a cowbell suspended on a spring, or a red tail light, or both, was attached to the last car of a pulled trip or the first car of a pushed trip to warn men working or walking in the haulageway of an approaching train (see figs. 3 and 4.) In many of the installations the power for the warning light is furnished by an electric cap-lamp storage battery; at one mine an electric-light wire runs from the trolley locomotive, through the "V" on the gable-bottom cars, to the tail light on the last car of the train.

Locomotives

Trolley locomotives operating on 250- or 275-volt direct current and 4 to 10 tons in size are used for main-line haulage; however, only one 10-ton locomotive was being used. One mine used 6-ton storage-battery locomotives for gathering purposes and 8-ton trolley locomotives for main-line haulage. The maximum distances hauled with the locomotives were 1,000 to 5,000 feet, with an average maximum distance of 2,770 feet for all mines.

In 2 of the 19 mines, diamond-shaped trolley poles are used on the locomotives instead of the conventional trolley pole. With the diamond-shaped trolley pole, the locomotive can travel in either direction without reversing

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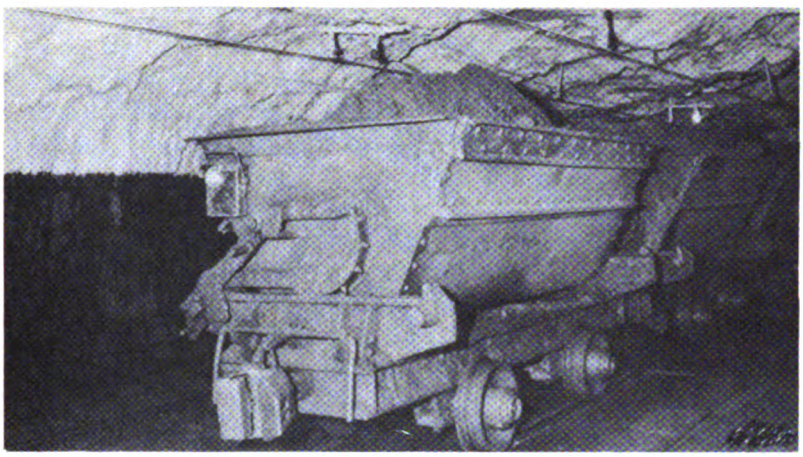

Figure 4. - Four-ton, rocker, dump-type car with storage-battery tail light on rear.

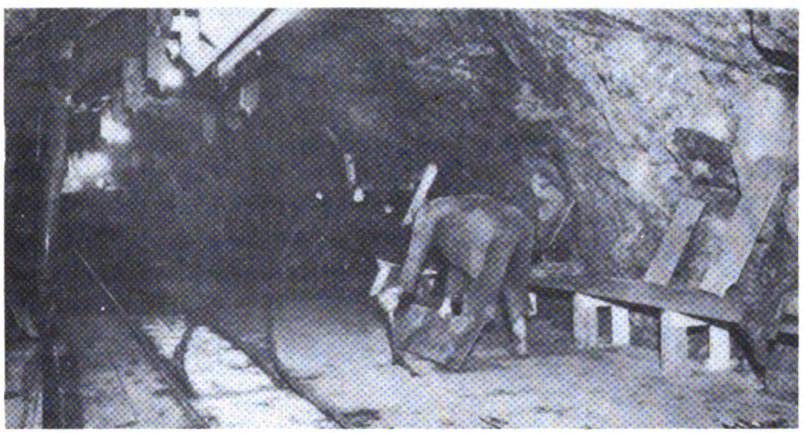

Figure 5. - Steel flush plate over haulage-track switch throw.

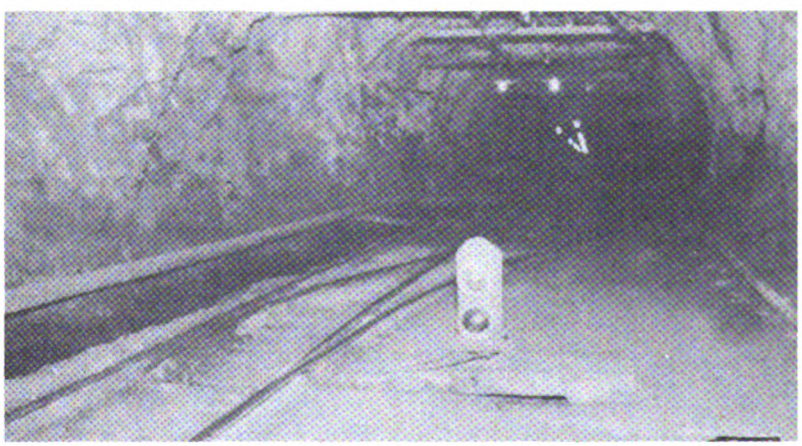

Figure 7. - Switch-stand signal lights operated from bridle bar.

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the trolley pole, and in low and narrow drifts the hazards of back-poling usually encountered with the conventional trolley pole are eliminated. Eighteen of the 19 mines had lights and bell, or lights and siren, or lights, bell, and siren on the locomotives for warning men working or walking on the haulageways. In one mine the locomotives were equipped with bells but not with lights.

Although sand is used to obtain better traction between the rails and the wheels on a few locomotives, most locomotives do not use any traction material. In three mines, water was used to increase traction; and water tanks were installed on the locomotives in one mine. It was stated that fine iron ore when ground under the wheels of a locomotive formed a slippery coating that reduced the friction between rails and wheels; water washed the slippery coating of iron ore off the rails and left them clean, this gave better traction and a better conductor for the electric current.

Track

The trend is toward the use of 60-pound rails laid to a 30-inch gage in many of the new main-line haulage tracks. Sixty-pound rails are used in nine mines, 45-pound rails in two mines, 40-pound rails in seven mines, and 30-pound rails in one mine. Thirteen mines are equipped with 24-inch gage track, five with 30-inch gage, and one with 36-inch gage. The radius of curves ranges from 30 to 100 feet; most tracks having a 50- to 75-foot radius curve. Generally, track grades are kept at 0.50 to 0.75 percent, usually in favor of the loads; however, a 3-percent grade was necessary at one mine.

Angle splice bars are used at rail joints, although in a few of the mines the rail joints have been welded to form a jointless track. The jointless track increases the life of the rails, reduces maintenance to rolling stock and track, and makes a better electrical conductor for the return of the direct-current circuit than the conventional jointed track.

Where the rail joints are not welded, the general practice is to bond the joints and cross-bond the rails at 200-foot intervals; however, the cross-bond interval is indefinite at some of the mines, and at a few mines the rail joints are neither bonded nor welded.

Thirteen of the mines are equipped with split-switch points, three mines with stub-switch points, and three mines have both split- and stub-switch points. Generally, cast manganese-steel frogs are used; a few mines have frogs made in the mine shops by bolting, riveting, or welding pieces of rail onto a plate. Generally, frogs, guardrails, and lead rails are blocked with wooden toe guards to prevent persons from catching their feet in them; however, this excellent safety feature was being neglected in a few mines.

Flat right-angle, upright stand, and flat parallel switch throws are used. Four mines were equipped with spring switches on the main-line haulage track, and air-operated spring switches were used on the main-line haulage track at one mine. At another mine, a steel flush plate (fig. 5) was installed over main-line haulage-track switch throws to eliminate the tripping hazard.

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Generally, untreated wooden ties 4 to 6 inches thick and spaced at 18- to 24-inch intervals are used on haulage tracks. Ties dipped in creosote are used at one mine. At some mines three to four steel spacer bars are used for each length of rail in addition to the wooden ties.

Electric-light signal systems installed overhead or on switch stands are generally used where more than one haulage crew is operating on one level. These signal systems are operated in any of the following ways: (1) By hand-controlled switches (fig. 6), (2) by trolley-contact switches, (3) by contact made by track switches, and (4) on a light stand operated by a bridle bar (fig. 7). At many mines, two electric-light bulbs of the same color are used in signal systems, so that one bulb of that color will still be available if a bulb is broken or burns out.

SHAFT STATIONS AND HOISTING SHAFTS

The larger mines have relatively elaborate shaft stations, which are necessary to handle men, timber, supplies, rock, and a large tonnage of ore with a minimum of delay. Usually, double-track haulage is installed at the shaft station, and the track runs parallel to the shaft to enable side-dumping of ore cars into the storage pockets. Generally, a run-around drift or crosscut is used for loading and unloading men and supplies from the side of the shaft opposite the storage pockets so as not to interfere with dumping of cars. Where large tonnages of ore are anticipated from one level, double-track haulage crosscuts are driven in rock from the shaft to the ore body. (See table 3.)

Dumping Cars

Several methods of dumping ore cars at the shaft station are used. Rocker-dump cars are dumped (1) by hand, (2) by placing one end of a steel bar or pipe against the floor and the other end against the side of the slowly moving car, or (3) by a compressed-air-cylinder jack when the car is stopped. The Granby-type car is dumped (1) by compressed-air-cylinder jack when the car is stopped or (2) by running a roller on the side of the car over a camel-backed portable ramp. All gable-bottom cars are dumped by hand. The solid box-type cars are dumped in a two-car rotary dump (fig. 8), and the drop-side-dump box-type cars are dumped by a compressed-air-cylinder jack when the cars are stopped.

Users of the rotary dump state that the savings in cost and maintenance of the more simply constructed solid-box-type car, as compared with the cost and maintenance of the more complicated side-dump cars, helps to pay for the rotary-dump unit in a few years. The rotary-dump units can be moved from level to level and used during the life of a large mine.

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Figure 6. - Hand-operated block-signal light.

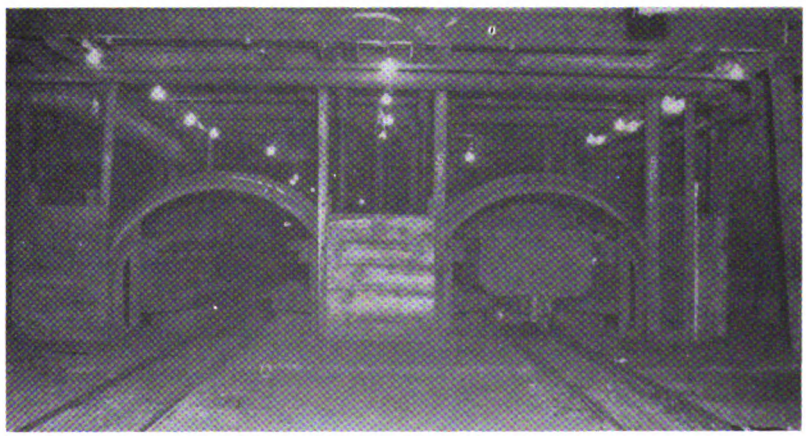

Figure 8. - Twin two-car rotary dumps.

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TABLE 3. - Stations and Shafts

Mine and mining methods	Shaft Stations						Hoisting Shafts							
	Car dumping method	Storage Pockets			Measuring pocket gates		Vertical or inclined	Inside dimensions	Number compartments	Type		Active shaft levels. Depth in feet	Ore hoisted	Hoisting shaft, depth feet
		Capacity tons	Gates Type	Gates Operated	Type	Operated				Timber	Lath			
A														
Radial top slicing	Hand	Dump directly into skip through a slide.					Vertical	14 ft. 4 in. by 10 ft. 2 in.	1 cage 2 skip 1 other	Wooden	Wooden	450	Yes	500
B														
Slicing	Hand	90	Arc	Air	None		Vertical	11 by 14 ft.	1 cage 2 skip 1 other	Wooden	Wooden	208	Yes	350
C														
Stoping and sublevel caving	Air cylinder	27	Steel overcut	Air	None		Vertical	6 by 16 ft.	2 cage and skip 1 other	Wooden	Wooden	900	Yes	950
D														
Top slicing and sublevel caving	Pipe against side of moving car.	120 and 200	Fingers and overcut plate.	Air Air	Overcut plate	Air	Vertical	6 by 18 ft.	2 cage and skip 1 other	Wooden to 1306 level steel to bottom.	Wooden to 1306 level, no lath to bottom.	1,306 1,506	Yes Yes	1,579
E														
Sublevel stoping	Air cylinde	110	Overcut plate.	Air	Overcut plate	Air	Vertical	10 ft. by 14 ft. 10 in.	1 cage 2 skip 1 other	Steel	Wooden	1,000 1,200	Yes Yes	1,286
F														
Sublevel caving	Bar against side of moving car.	350	Arc	Air	Hinged plate	Air	Vertical	11 ft. 6 in. by 18 ft. 8 in.	1 cage 2 skip 1 other	Steel	Concrete	3,106 3,304 3,502	No Yes No	3,586
G														
Sublevel caving	Granby type by air, rocker cars by hand.	210	Arc	Air	Overcut plate	Air	Vertical	10 ft. by 23 ft. 6 in.	2 cage 2 skip 1 other	Steel	Concrete	2,851 3,055	Yes Yes	3,150
H														
Top slicing	Hand	60	Arc	Hand	None		Vertical	10 ft. by 18 ft.	1 cage 2 skip 1 other	Steel	Concrete	221	Yes	300
I														
Sublevel stoping	Air cylinder	Dump directly into skip through a slide.					Vertical	6 by 10 ft. at collar, 6 by 20 ft. at bottom.	2 skip and cage at collar	Wooden	Wooden	1,930 2,106	No Yes	2,169
J														
Radial top slicing	Pipe against side of moving car.	240	Vertical fingers	Air	Overcut plate	Air	Vertical	10 ft. 6 in. by 14 ft. 10 in.	1 cage 2 skip 1 other	Concrete wood, and steel.	Wooden	1,310 1,435 1,540	Yes Yes Yes	1,620
K														
Top slicing and sublevel caving	Hand	9	Overcut plate	Air	None		Vertical	9 by 13 ft.	1 cage 2 skip 1 other	Wooden	Wooden	625 825	Yes Yes	855
L														
Sublevel caving and sublevel stoping	Movable camelback and air cylinder	24	Overcut plate	Air	None		Vertical	12 ft. by 17 ft. 6 in.	1 cage 2 skip 1 other	Steel	Steel sheets	1,600 1,750 2,050 2,200	Yes No Yes No	2,352
M														
Sublevel caving	Bar against side of car and air cylinder.	310	Arc	Air	Hinged plate	Hand or air	Vertical	10 ft. by 16 ft. 10 in.	1 cage 2 skip 2 other	Steel	Creosoted wood lath and concrete	2,443 2,590 2,737 2,877	No Yes Yes Yes	3,036
N														
Top slicing and sublevel stoping and hand	Air cylinder	125	Fingers and overcut plate	Air	Overcut plate	Air	Vertical	10 ft. by 14 ft. 10 in.	1 cage 2 skip 1 other	Steel and wooden	Wooden	1,650 1,854	Yes Yes	1,938
O														
Top slicing and sublevel stoping	Hand	140	Vertical fingers on rollers	Air	Overcut plate	Air	Vertical	17 ft. in diameter first 1000 ft. then 12 by 14 ft.	1 cage 2 skip 1 other	Steel and concrete. Wooden	Steel and concrete. Wooden	787 1,316	Yes Yes	1,370
P														
Sublevel caving	Rotary dumps	250	Arc	Air	Arc	Air	Vertical	12 by 20 ft.	2 cage 2 skip 1 other	Steel	Wooden	2,598 2,854 3,119	No Yes Yes	3,225
Q														
Sublevel caving	Granby type by air. Rocker dump by air and by hand.	150	Arc	Air	Hinged plate	Air	Vertical	10 ft. by 16 ft. 8 in.	1 cage 2 skip 1 pipe 1 ladder	Steel	Concrete to 11th. Wooden 11th to bottom	1,764 1,919	No Yes	1,984
R														
Sublevel caving	Rocker dump by hand. Granby type by air.	None	-	-	Overcut plate	Air	Inclined 68 degrees	10 ft. by 18 ft. 8 in.	1 cage 2 skip 2 other	Steel	Concrete and wooden	Vertical depths 1,969 2,336	No Yes	2,432
S														
Sublevel caving	Hand and air cylinder	75	Rail fingers	Air	Hinged plate	Air	Inclined 70 degrees	6 ft. by 17 ft. 6 in.	2 skip 1 other	Steel	Wooden and concrete lining.	1,300 1,400	Yes Yes	1,500

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Storage Pockets

A few of the mines do not have ore-storage pockets but dump directly into the skips through a slide or dump into a small pocket that holds one skipload of ore. This method requires the haulage crew to stay at the shaft station while a trainload of ore is dumped and hoisted.

Most of the mines are equipped with storage pockets at the shaft station, which hold 25 to 350 tons of iron ore. The pockets usually are divided into three compartments, so that three grades of ore can be dumped at one time. In most mines, a measuring pocket holding one skipload of ore directly below the storage pockets helps to speed hoisting and prevents spillage into the shaft from overloaded skips.

Gates or doors used at the bottom of the storage pockets are (1) steel arc-shaped gates operated either by hand or by compressed-air cylinders, (2) steel overcut-plate gates operated by compressed-air cylinders, or (3) vertical finger gates (fingers made of 2- by 2-inch steel bars or steel rails) operated by compressed-air cylinders. Measuring pocket gates may or may not be the same as the gate on the storage pocket, but one of the types described above is ordinarily used. At some of the mines, a hinged-plate gate, operated either by hand or by a compressed-air-cylinder jack through a toggle connection, is used on the measuring pockets.

Auxiliary Storage Trenches

During the last decade, trenches at underground shaft stations (fig. 9) have been used at several mines for auxiliary storage space where the station pockets could not handle the several grades of ore and waste, or where the ore was so wet or sticky that it caused considerable trouble and delay in transferring the ore from the storage pockets to the skips. In one mine where the rock at the shaft station was so badly fractured that it was not considered safe to excavate for a large storage pocket, a storage trench of 135 tons capacity was excavated along the track at the shaft station.

Either one or two trenches are installed at a shaft station. Where two trenches are used, the trenches are on the same side of the track and have a common opening on one end directly over the measuring pocket. Trenches range in size from 90- to 700-ton capacity, 3 to 17 feet deep, 4-1/2 to 9 feet wide, and 50 to 100 feet long. Several of the trenches have the floor and sides lined with concrete with rails imbedded in the concrete.

The wet or sticky ore is dumped directly into the trenches from the underground cars. The ore is scraped from the trenches into a measuring pocket that holds one skipload of ore, or the ore can be scraped directly into the skip through the open measuring pocket if desired. Scrapers 48 to 60 inches wide, pulled by 25- to 40-horsepower electrically operated scraper hoists, are used to move the ore from the trenches to the skips.

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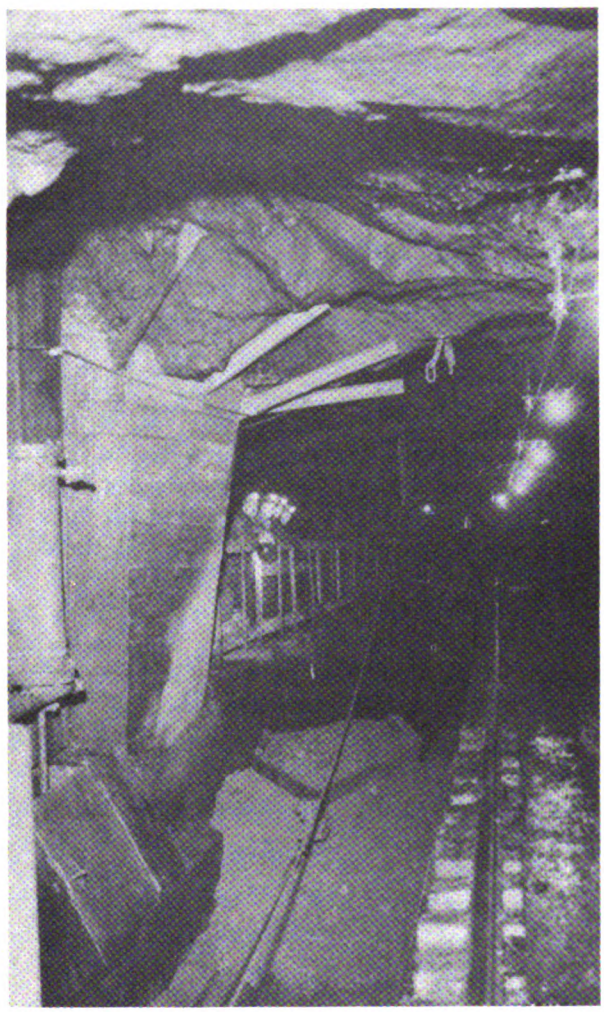

Figure 9. - Ore-storage trench at shaft station.

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At one mine, a sublevel storage drift 130 feet long was driven 32 feet below the haulage level at the shaft station in place of a storage pocket. The ore is dumped from the mine cars on the haulage level to the sublevel drift through three open raises spaced at 30- to 35-foot centers. The ore is scraped from the sublevel drift to a two-compartment measuring pocket, each compartment holding one skipload of ore.

Mine officials who have used the trench system of storing ore at shaft stations state that the trenches are valuable as auxiliary storage, but they should not entirely replace the storage pockets. When trenches are used as main storage or the only storage at shaft stations, serious delays in ore hoisting are often encountered owing to breakdowns of the scraper hoists, scrapers, or pulling cables.

Hoisting Shafts

Of the 19 mines under discussion, 17 use vertical hoisting shafts and 2 use inclined hoisting shafts. The cross-sectional dimensions (inside of timber) of the hoisting shafts range from 6 by 10 feet for a two-compartment shaft to 12 by 20 feet for a five-compartment shaft. Most of the shafts have four compartments - one cage compartment, two skip compartments, and one ladder and miscellaneous compartment. Five of the shafts have five compartments; two of these have two cage compartments, two skip compartments, and one ladder and miscellaneous compartment; the other three five-compartment shafts have one cage compartment, two skip compartments, one ladder compartment, and one counterweight or miscellaneous compartment.

One four-compartment shaft is 17 feet in diameter for the first 1,000 feet and 12 by 14 feet in cross section for the remaining 370 feet; the circular part of the shaft is timbered with steel and concrete. Most of the shafts have steel timber and wooden lath, some have wooden timber and wooden lath, and some have concrete lath.

Ore is hoisted from one level at eight mines, from two levels at nine mines, and from three levels at two mines. Ore is hoisted from depths over 3,000 feet at three mines, from depths between 2,000 and 3,000 feet at four mines, from depths between 1,000 and 2,000 feet at seven mines, and from depths less than 1,000 feet at five mines. The bottom of the deepest hoisting shaft is 3,586 feet vertically below the shaft collar.

SKIPS, CAGES, AND HOISTS

Skips

Ore is hoisted in balance at all of the mines under discussion. Self-dumping aluminum-alloy or steel skips are used; 16 of the mines have steel skips and 3 of them have aluminum-alloy skips. Skips range in size from 55-cubic-foot, 3-1/4-ton capacity to 210-cubic-foot, 12-ton capacity. When hoisting with steel skips, the average ore load is about 64 percent and the dead load about 36 percent of the total load of skip and ore; whereas, when

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hoisting with aluminum-alloy skips, the average ore load is about 75 percent and the average dead load is about 25 percent of the total load of skip and ore. For a skip of a given volume, the ore load can be increased about 16 percent when using an aluminum-alloy skip as compared to a steel skip with the same total load of skip and ore; however, when hoisting with two skips in balance, the maximum unbalanced load is equal to the weight of ore plus the weight of the unbalanced rope. (See table 4.)

Generally, wooden skip guides are used, but standard 80-pound rail skip guides are used at one mine.

Cages

Ore is not hoisted in cars on cages at any of the mines. Double-deck and single-deck cages made of steel or aluminum alloy are used to transport supplies and men. Steel cages are used at 15 of the 19 mines, and aluminum-alloy cages are used at 4. At 2 of the mines the skips are suspended below the cages. Generally, the cages are large enough to transport a truckload of 8-foot timber loaded horizontally.

Cages, or cages with suspended skips, are hoisted in balance at 4 of the mines; at the other mines, the cages are balanced with counterweights running on wooden guides, rails, or in pipes. The number of men loaded on a cage varies from 12 on a single-deck cage to 75 on a double-deck cage.

Generally, wooden cage guides, one for each side of the cage, are used. However, at one mine, two 6- by 10-inch wooden guides are used for each side of the cage; the man cage in this mine is equipped with eight steel-spiked cam safety catches instead of the four catches generally used on cages of the other mines. Monthly drop tests of the safety catches, dropping the cage from a standing position, are made at all mines except one, where a weekly drop test is made.

Hoists

Electric hoists are used at 18 of the 19 mines under discussion, and steam hoists are used at 1 mine. The electric hoists range from 150 to 3,000 horsepower and are operated on 440- to 2,300-volt alternating current or on 200- to 600-volt direct current. One of the latest hoist installations, using the Ward Leonard amplidyne exciter system of hoist control, has one 1,500-horsepower, 600-volt, direct-current motor on the cage hoist and two 1,500-horsepower, 600-volt, direct-current motors on the skip hoist. Identical motors are used on the cage and skip hoists, so that fewer repair parts need to be kept on hand.

Cylindrical-type drums ranging in size from 5-foot diameter and 5-1/2-foot face to 12-foot diameter and 17-1/2-foot face are used.

Generally, one post-type gravity brake with either air or hydraulic release is used on each drum. An additional hand-operated brake for emergency use has been installed on several hoists.

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TABLE 4. - Hoisting

Mine and mining method	Skips				Cages				Hoists						Rope	
		Capacity							Horsepower and voltage		Size of drums, feet				Speed, f.p.m., and diameter, inches	
	Number	Cu. ft.	Tons	Weight, lbs.	Number	Capacity, men	Weight, lbs.	Balance	Cage	Skip	Cage Diam.	Cage Face	Skip Diam.	Skip Face	Number and type brakes Cage and skip	Cage	Skip
A																	
Radial top slicing	2-steel	72	3-1/4	4,000	1-steel	15	6,400	Counter-weight on wooden guides...	150 2,300 a.c.	250 2,300 a.c.	Single 8	8	Single 8	8	One air-release brake on each drum.	400' 1-1/8"	400' 1-1/8"
B																	
Slicing	2-steel	55	3-1/4	3,000	1-steel	20	3,000	Counter-weight on wooden guides.	150 2,200 a.c.	300 2,200 a.c.	Single 7	6	Single 7	6	One post-type and one hand-operated brake on each drum.	400' 1-1/8"	1,000' 1-1/4"
C																	
Stoping and sublevel caving	2-steel	67	3-1/2	4,200	1-steel	20	6,250	With skip, in supply shaft.	250 2,200 a.c.	350 2,200 a.c.	Single 6	6	Single 6	6	One air-operated brake on each drum. Extra hand brake on cage drum,	750' 1"	1,200' 1"
D																	
Top slicing and sublevel caving	2-steel	82	5	4,865	2-steel	12	5,300	One skip suspended below each cage.	500 2,200 a.c.		Double 9	10			Hydraulic post-type and hand brake on each drum.	1,000' 1-3/8"	1,200' 1-3/8"
E																	
Sublevel stoping	2-steel	100	6	5,500	1-steel	25-32	4,000	Counter-weight on wooden guides.	350 2,200 a.c.	600 2,300 a.c.	Single 9	8-1/2	Double 8	5	Hydraulic post-type on each drum. Extra hand brake on cage drum.	1,000' 1-1/4"	1,000' 1-1/4"
F																	
Sublevel caving	2-aluminum	157	9	7,000	1-steel	44	13,000	Counter-weight on wooden guides.	600 2,200 a.c.	1,250 2,200 a.c.	Double 10	10	Double 10	10	One hydraulic post-type brake on each drum.	1,000' 1-3/8"	1,200' 1-1/2"
G																	
Sublevel caving	2-steel	169	10	10,000	2-steel	54	10,000	Cages in balance.	500 2,200 a.c.	1,500 2,200 a.c.	Single 12	13-1/2	Single 12	17-1/2	One air-operated post-type brake on each drum.	1,000' 1-3/8"	1,500' 1-3/4"
H																	
Top slicing	2-steel	100	5	-	1-steel	24	-	Counter-weight in pipe.	200 440 d.c.	200 440 d.c.	Single 5	5-1/2	Single 5	5-1/2	One air-operated post-type brake on each drum.	400-500' 1-1/8"	400-500' 1-1/8"
I																	
Sublevel stoping	2-steel	65	4	-	2-steel	12	4,500	One skip suspended below each cage.	600 2,200 a.c.		Single 10-1/2	10			One post-type and one hand brake.	1,000' 1-1/4"	1,200' 1-1/4"
J																	
Radial top slicing	2-steel	90	5-1/2	7,500	1-aluminum	50	6,425	Counter-weight in pipe.	400 2,200 a.c.	700 2,200 a.c.	Single 10	8	Single 10	8	One air-release and one hand brake on each drum.	1,000' 1-1/4"	1,500' 1-1/4"
K																	
Top slicing and sublevel caving	2-steel	90	4-1/2	4,500	1-steel	24	6,000	Counter-weight on wooden guides.	150 440 d.c.	400 2,300 a.c.	Single 6	8	Single 10	10	One air-release and one hand brake on each drum.	750' 1-1/8"	1,000' 1-1/4"
L																	
Sublevel caving and sublevel stoping	2-steel	210	12	12,000	1-aluminum	75	12,000	Counter-weight in pipe.	1,500 600 d.c.	3,000 600 d.c.	Single 12	8	Double 12	8	One hydraulic post-type brake on each drum.	1,600' 1-7/8"	1,200'-2,400' 1-7/8"
M																	
Sublevel caving	2-aluminum	167	9-1/2	6,500	1-steel	50	13,000	Counter-weight in pipe.	600 2,300 a.c.	2,300 600 d.c.	Double 10	10	Double 10	10	One hydraulic post-type brake on each drum.	1,000' 1-3/8"	1,850' 1-1/2"
N																	
Top slicing and sublevel stoping	2-aluminum	-	6	3,315	1-aluminum	50	-	Counter-weight in pipe.	400 2,300 a.c.	600 2,300 a.c.	Single 10	10	Single 10	10	Hydraulic post-type on each drum. Extra hand brake on cage drum.	700' 1-3/8"	1,100' 1-3/8"
O																	
Top slicing and sublevel stoping	2-steel	90	5-1/2	7,500	1-aluminum	50	6,425	Counter-weight in pipe.	200 200 d.c.	500 525 d.c.	Single 8	8	Single 8	8	One air-release post-type brake on each drum.	1,000' 1-1/4"	1,500' 1-1/4"
P																	
Sublevel caving	2-steel	145	8-1/2	8,000	2-steel	50	5,000	Cages in balance.	600 2,200 a.c.	1,000 2,200 a.c.	Double 10	6	Double 12	6-1/2	One hydraulic post-type brake on each drum.	1,000' 1-3/8"	1,200' 1-5/8"
Q																	
Sublevel caving	2-steel	96	6	8,390	1-steel	36	12,000	Counter-weight in pipe.	Steam hoists. Maximum h.p. 2,000; present h.p. 1,500		Double 6	4-2/3	Double 10	5-1/2	One hydraulic post-type brake on each drum.	1,500' 1-1/4"	1,750' 1-1/4"
R																	
Sublevel caving	2-steel	112	6-1/2	-	1-steel	25	-	Counter-weight on rails.	400 2,300 a.c.	1,000 2,300 a.c.	Single 10	12	Single 10	12	One hydraulic post-type brake on each drum.	1,000' 1-3/8"	1,600' 1-3/8"
S																	
Sublevel caving	2-steel	84	6	5,700	Only in supply shaft 1-steel	54	12,500	With rock skip.	500 2,200 a.c.	972 2,200 a.c.	Single 12	9	Single 12	13-1/2	One hydraulic post-type brake on each drum.	800' 1-3/8"	1,000' 1-3/8"

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All hoists are equipped with Lilly overspeed and overwind control devices. Some mines have an additional limit control contact installed in the headframe, so that if the skip or cage is pulled too high an electrical contact is made in the engine house, which applies the brake and shuts off the power. Most hoisting installations have an additional warning device called the slack-rope warning, which will notify the hoisting engineer when the skip or cage is stuck and slack rope is being released from the drum. The slack rope will touch a contact located between the head frame and the hoist house and electrically convey a signal to the hoisting engineer by means of a light, horn, or bell. Automatic safety control equipment must be properly installed, inspected, adjusted, and maintained in order to be of any value; hoisting accidents have occurred where these precautions have not been followed.

Round, steel-stranded hoisting ropes 1 to 1-7/8 inches in diameter are used. Rope speeds when hoisting and lowering men are generally less than rope speeds when hoisting ore. Hoisting speeds for handling men range from 400 feet per minute at shallow mines to 1,600 feet per minute at deep mines, whereas hoisting speeds for handling ore range from 400 feet per minute at shallow mines to 1,850 feet per minute at deep mines. At one mine, it is expected that ore will be hoisted at a speed of 2,400 feet per minute when full production is reached.

HEAD FRAMES AND STOCK PILE HAULAGE

Head Frames

Head frames are constructed of steel and range in height from 95 to 197 feet above the shaft collar. The height from the shaft collar to the center line of the sheave wheels ranges from 85 to 179 feet. Ore pockets (fig. 10) in the head frame, from which railroad cars are loaded during the shipping season, range in capacity from 50 to 1,000 tons. (See table 5.)

Generally, overcut arc-type gates are used at the head frame loading pockets; however, overcut steel-plate gates, rail-finger gates, steel clamshell-type gates, and horizontal steel-plate gates on rollers are used. Most of the overcut arc-type gates are operated by hand, and a few are operated by compressed-air cylinders. The other types of gates are compressed-air-cylinder operated.

At 10 mines, the brakes on railroad cars are operated by hand when spotting the cars under the loading pockets and when moving the cars to and from the pockets. At 9 mines, the brakes are operated by using compressed air. Generally, employees handling railroad cars use safety belts when the brakes are operated by hand and do not use safety belts when the brakes are operated by compressed air; in a few instances in each case this general rule is not followed.

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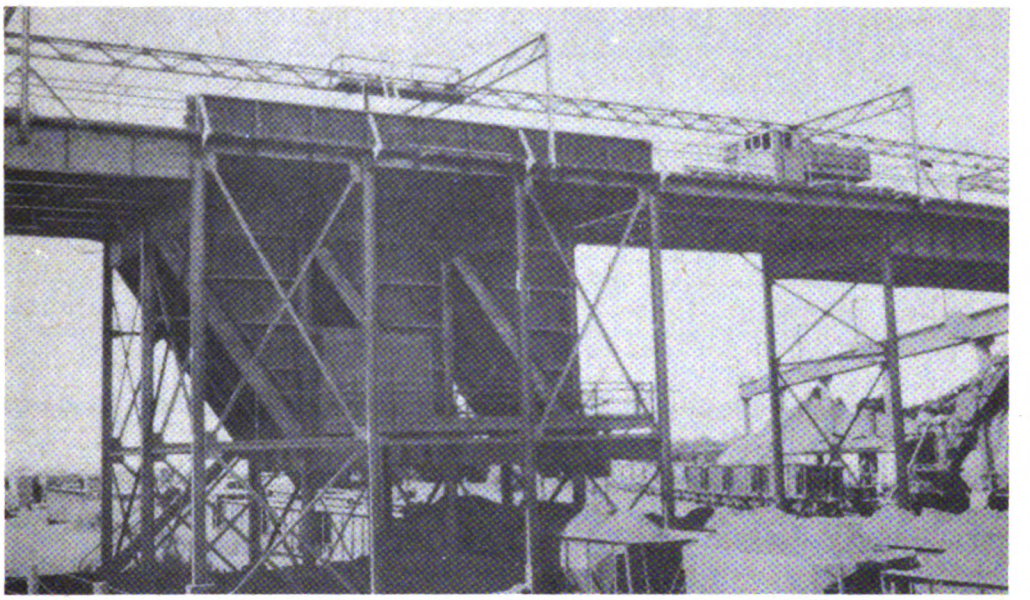

Figure 10. - Headframe loading pocket and steel monoleg stocking trestle.

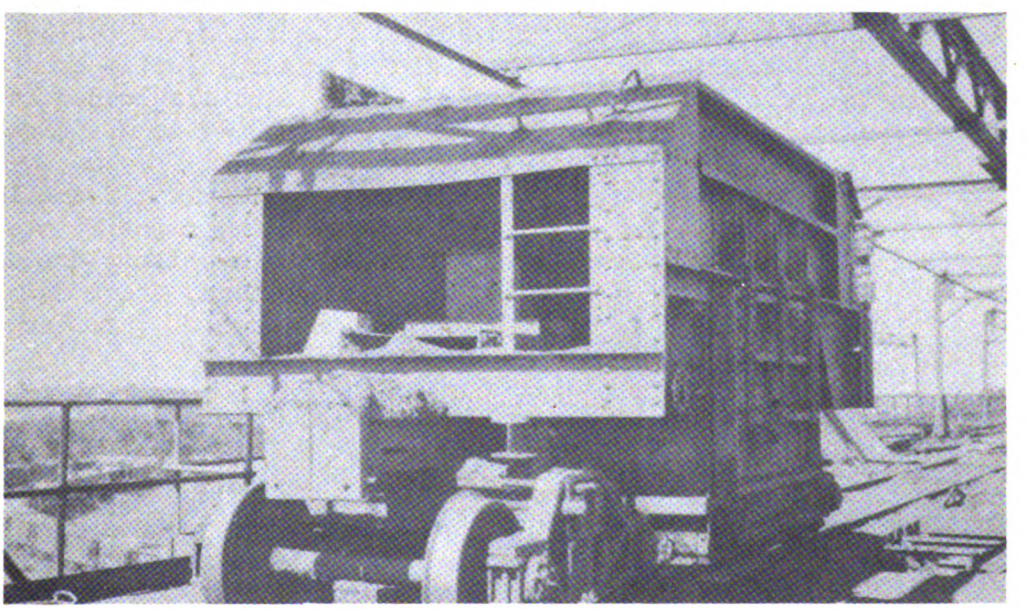

Figure 11. - Ten-ton remote-control-operated larry car.

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TABLE 5. - Head frame and stockpile haulage

Mine and mining methods	Head frame						Railroad cars		Stockpile haulage		
		Height in feet		Pocket							
	Material	To center sheaves	To top	Capacity tons	Gates Type	Gates Operated	Spotted	Safety belts	Car type	Capacity tons	Power
A											
Radial top slicing	Steel	85	95	50	Arc	Air	Air	No	Side-dump gable bottom.	6	Trolley locomotive.
B											
Slicing	Steel	85	100	65	Arc	Hand	Hand	Yes	Side-dump.	3-1/4	Endless rope.
C											
Stoping and sublevel caving	Steel	110	114	150	Arc	Hand	Hand	Yes	Side-dump gable bottom.	3-1/2	Endless rope.
									Side dump	3-1/2	Trolley locomotive.
D											
Top slicing and sublevel caving	Steel	105	120	50	Arc	Hand	Hand	Yes	Side-dump gable bottom.	5	Remote control.
E											
Sublevel stoping	Steel	120	137	100	Arc	Hand and air	Hand	Yes	Dump truck.	6-1/4	Diesel engine.
F											
Sublevel caving	Steel	146	167	75	Overcut plate	Air	Air	No	Side-dump gable bottom.	9	Remote control.
G											
Sublevel caving	Steel	92	108	600	Arc	Hand	Air	Yes	Side-dump.	10	Remote control.
									Three-way dump.	10	Direct control.
H											
Top slicing	Steel	86	-	50	Arc	Hand	Air	No	Three-way dump.	5	Trolley locomotive.
I											
Sublevel stoping	Steel	100	-	75	Arc	Hand	Hand	No	End-dump with 180° swing.	4	Trolley locomotive.
J											
Radial top slicing	Steel	95	109	250	Arc	Hand	Hand	Yes	Side-dump gable bottom.	6	Remote control.
K											
Top slicing and sublevel caving.	Steel	120	130	100	Arc	Hand	Hand	No	Side-dump gable bottom.	5	Remote control.
L											
Sublevel caving and sublevel stoping	Steel	162 and 179	197	1,000	Horizontal roller type	Air	Air	Yes	Three-way 180-degree hydraulic dump.	12	Direct control.
M											
Sublevel caving	Steel	148	164	300	Overcut plate	Air	Air	No	Side-dump gable bottom.	19	Direct control.
N											
Top slicing and sublevel stoping	Steel	130	-	200	Arc	Hand	Hand	Yes	Side-dump.	6	Remote control.
O											
Top slicing and sublevel stoping	Steel	95	109	200	Arc	Hand	Hand	Yes	Side-dump gable bottom.	5-1/2	Endless rope.
P											
Sublevel caving	Steel	114	131	125	Clam-shell type	Air	Air	No	Three-way hydraulic dump.	10	Trolley locomotive.
Q											
Sublevel caving	Steel	104	116	150	Arc	Air	Air	No	Side-dump gable bottom.	6	Trolley locomotive.
R											
Sublevel caving	Steel	75	-	90	Arc	Hand	Hand	Yes	Side-dump.	7	Remote control.
S											
Sublevel caving	Steel	144	160	100	Rail fingers	Air	Air	Yes	End-dump.	6	Trolley locomotive.
									Side-dump.	6	Trolley locomotive.

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Stock-Pile Haulage

Because the rigorous climate of the Lake Superior district prevents lake shipping of iron ore in winter, the underground iron ore mined then is stock-piled on the surface near the hoisting shaft and loaded into railroad cars by power shovels during the shipping season.

Several mines are equipped with permanent, steel, monoleg stocking trestles (fig. 10), but temporary wooden-bent stocking trestles are used at many mines. The iron ore is transported from the head frame to the stock piles in (1) side-dump gable-bottom cars, (2) one-side-dump cars, (3) end-dump cars, (4) end-dump cars with a 180-degree swing, (5) three-way-dump cars, (6) three-way-dump cars with a 180-degree swing, and (7) Diesel-operated dump trucks. The stock-pile haulage cars, which range in capacity from 3-1/2 to 19 tons, are operated by (1) direct control, where the operator rides on the car, (2) remote control, where the operator stays at the head frame (fig. 11), (3) trolley locomotive, and (4) endless rope. Two of the cars have hydraulically operated dumps.

At one mine,[10/] three 210-cubic-foot stock-pile cars running on 60-pound rails with 42-inch gage track are used. These eight-wheel, two-truck cars not only dump forward and to each side, but also will dump at any angle in a 180-degree half circle. A man housed in a cab rides on the car, which is powered by four 15-horsepower direct-current motors, one motor on each set of two corner wheels. It is equipped with oil-pressure dump cylinders and brakes and travels at a maximum speed of 20 miles per hour. The cars are nearly 20 feet long, and each weighs 29,000 pounds.

ACCIDENT STATISTICS

Table 6 shows the relative severity of injuries, by causes, for the underground iron-ore mines of the district for 1944 and 1945. The relative severity is given in days lost per injury, as the number of man-hours worked in each occupation or for each cause was not available.

Haulage that includes hoisting and loading rock and ore ranks seventh in relative severity, with 158.5 days lost for each lost-time injury, this figure is below the average of 207.9 days lost for all causes. Injuries from (1) electricity, (2) explosives, (3) inrushes of mud and water, (4) falls and slides of rock and ore, (5) flying objects, and (6) drilling equipment were more severe than injuries from haulage. About 15 percent of the total number of injuries occurring during the 1944-45 period were from haulage, hoisting, and loading rock and ore; exclusive of the injuries in the "not classified" heading, injuries from haulage ranked third in number.

Table 7 shows the causes, number, and relative severity of the 210 injuries that are listed under "haulage, hoisting, and loading ore and rock" in table 6.

10/ Allen, C. W., and Moore, L. C., Opening the Mather Mine: Am. Inst. Min. and Met. Eng., Min. Technol., May 1945, p. 22.

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TABLE 6. - Relative severity of injuries, by causes, 1944-1945, exclusive of open-cut mines

Cause	Days lost	Number of injuries	Days lost per injury
Electricity	6,021	3	2,007.0
Explosives	12,605	8	1,575.6
Inrushes of mud and water	6,542	6	1,090.3
Falls and slides of rock and ore	137,992	239	577.4
Flying objects	6,761	37	182.7
Drilling equipment	7,637	46	166.0
Haulage, hoisting, and loading ore and rock	33,287	210	158.5
Persons slipping, stumbling, and falling	16,589	106	156.5
Machinery, moving	4,286	31	138.3
Falling material	18,030	142	127.0
Handling material	10,961	232	47.2
Hand tools	2,574	56	46.0
Not classified	20,679	250	82.7
All causes	283,964	1,366	207.9

TABLE 7. - Causes, number, and relative severity of injuries from haulage, hoisting, and loading ore and rock, 1944-1945

Cause of injury	Number of injuries	Total days lost	Days lost per injury	Order of relative severity
Loading tram cars at chutes	53	2,099	39.6	15
Dumping tram cars at shaft stations	18	509	28.3	18
Coupling tram cars and locomotives	15	971	64.7	9
Handling scraper ropes and blocks	13	436	33.5	17
Caught between haulage trains and obstructions	12	214	17.8	20
Handling scrapers	10	668	66.8	8
Working on grizzlies	10	178	17.8	19
Riding on locomotive	9	810	90.0	5
Running ore to scraper drifts	8	*6,183	772.9	4
Operating stock pile haulage	7	*6,382	911.7	3
Scraper hoist sprags loosened	7	401	57.3	10
Working at shaft pockets and skip pits.	7	291	41.6	13
Getting on and off moving trains	7	259	37.0	16
Struck by haulage train	6	*6,398	1,066.3	2
Putting tram cars on track	6	446	77.7	7
Handling mechanical loaders	6	325	54.2	12
Falling from stock pile trestles	4	346	86.5	6
Handling railroad cars	4	162	40.5	14
Hand loading ore	3	25	8.3	21
Hoisting (skips and cages)	2	*6,015	3,007.5	1
Miscellaneous	3	169	56.3	11
	210	33,287	158.5	

*Includes one fatal injury.

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Four fatal injuries occurred during 1944 and 1945, as follows: (1) A miner was struck by a run of ore from a stope mill while working in a slushing drift, (2) a track cleaner was run over by a pushed haulage train while he was cleaning track, (3) motorman fell to the ground from the trestle with locomotive and stock-pile car after having a collision with another locomotive, and (4) a man was thrown from a moving cage.

Loading tram cars at chutes was responsible for 53 of the 210 lost-time injuries, with 2,099 days lost; dumping tram cars at shaft stations was responsible for 18 lost-time injuries, with 509 days lost; coupling tram cars and locomotives caused 15 lost-time injuries, with 971 days lost; handling scraper ropes and blocks caused 13 lost-time injuries, with 436 days lost; and getting caught between haulage trains and obstructions caused 12 lost-time injuries, with 214 days lost. These five major causes of injuries were responsible for 111, or 52 percent, of the 210 lost-time injuries, but they only accounted for 4,229, or 13 percent, of the 33,287 days lost.

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